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HEAT RECOVERY SYSTEMS FOR SOLAR RADIATION AT MARITIME INFRASTRUCTURE FACILITIES

[1]Sandler Albert
Candidate of Technical Sciences, Associate Professor
ORCID: https://orcid.org/0000-0002-0709-0542
[2]Romanovska Olha
Senior Lecturer
ORCID: https://orcid.org/0000-0003-3386-836X
[3]Palagin Oleksandr
Candidate of Technical Sciences, Associate Professor
ORCID: https://orcid.org/0000-0002-6533-5894
[1]National University "Odessa Maritime Academy"
[2.3]Danube Institute of National University "Odessa Maritime Academy"
Ukraine

Abstract. One of the ways to solve the problem of energy saving is the development of technologies for deep utilization of heat from secondary energy sources of the marine complex. The introduction of such technologies allows for a significant increase in the efficiency of using the thermal potential of fuel and ensure its efficient use and improves the environmental situation by reducing emissions of harmful substances into the environment. The development and implementation of heat utilization technologies are associated with the need to solve a number of rather complex scientific and technical problems. Utilization technologies are usually implemented in the process of modernization or reconstruction of existing facilities. The task is addressed by implementing a low-potential heat utilization system. The system consists of Peltier elements made of bismuth telluride and silicon germanide. These elements are connected to the primary components by means of metal rods and switching units for connection to the power grid. The peculiarity of the application lies in using the area of noise barriers that enclose the highways of the maritime infrastructure.

Keywords: heat recovery, Peltier elements, noise barriers.

Introduction. In recent decades, there has been a rapid increase in the level of noise pollution caused by road transport. This negative impact is especially felt on the roads that run through the city and connect the port complexes of the maritime sector with highways.

This phenomenon is explained by the increase in traffic intensity, increased engine power and increased vehicle speeds. All these factors contribute to the problem of transport noise pollution, which is becoming an important component of the general socio-ecological problem of environmental protection. The noise that occurs during the movement of road transport has three main sources: exhaust gases, engine operation and the interaction of tires with the road surface. Part of the sound waves is absorbed by the road surface and the soil beneath it.

At the present stage, the task of minimizing the negative impact of transport noise on adjacent territories is actively taken into account in road construction and reconstruction projects. One of the most effective methods of noise protection is the creation of green spaces and the installation of special noise barriers (Fig. 1).

The main types of noise barriers for highways include: ground-mounted barriers and elevated barriers. Reflective screens with a height of 2 to 6 m can be made of reinforced concrete, metal, plastic, wood. These screens can also be made of metal profiles manufactured from steel or aluminum alloys. They are fixed in the ground on a strip foundation. The structure consists of prefabricated panels installed between supporting elements.

Fig. 1. Noise barriers along a highway

The most common version of the screen is galvanized perforated metal, up to 0.8 mm thick, painted with a polymer coating. The screen package also includes a wind/moisture-proof membrane that prevents excess moisture from getting on the sound-absorbing mineral wool. Sound absorption is provided by a non-combustible high-density mineral wool board. A distinctive feature of such panels is their high load-bearing capacity, without additional frame and reinforcement. The Z-Lock lock on the upper and lower edges of the panels creates additional stiffening ribs that easily cope with wind loads, as well as all mechanical influences and impulsive aerodynamic loads (Fig. 2).

Perforated panels are usually placed at a height of more than 1 meter from the roadway level when installed on the ground, and starting from 1 meter when installed in industrial facilities and in places where protection from noise from engineering equipment is required. The length of the screen protection can reach several kilometers [1]. Thus, the total area of the protective screens can be thousands of square meters.

Analysis of recent research and publications. To find rational ways to improve deep heat recovery systems, existing heat recovery systems were analyzed.

The most common system includes an air-water cooler. In this system, the coolant is used to heat water for secondary consumers.

Disadvantages of the device, which are due to the use of an air-water cooler:

- high cost of the cooler;
- the need to have a cooler for each compressor separately;
- leakage from water tubes is associated with water entering the working cavities of the compressor and leading to compressor failure;
- the complexity of repair and restoration work to maintain the cooler in working condition.

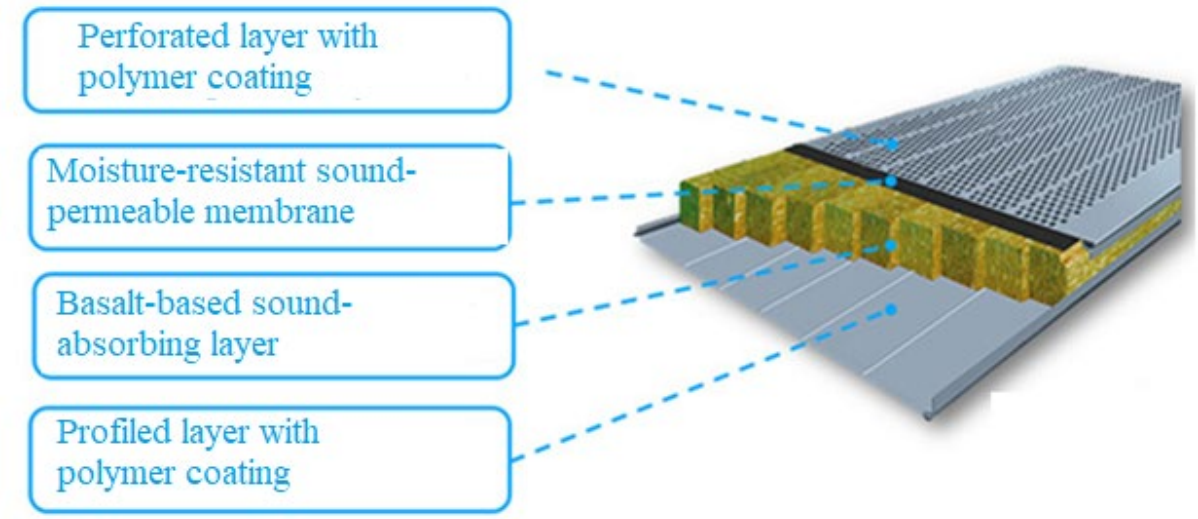

Fig. 2. Structure of the protective screen

To a large extent, the system is free from these disadvantages. It is based on an external cooler consisting of two semi-cylindrical bases that enclose the pipeline carrying the coolant. The primary parts of the Peltier elements made of bismuth telluride are mounted over the entire inner surface of the cooler. On the outer surface, additional cooling radiators and secondary parts of the Peltier elements made of silicon germanide are installed.

The disadvantages of the system, which are due to the use of Peltier elements exclusively, are as follows:

- the need for a sufficiently large module size for the effective conversion of thermal energy into electrical energy;
- the need for high heat transfer rate between the coolant and the Peltier element;
- the high cost of a cooler based on the specified module [2, 3].

Purpose and objectives of the study. The purpose of the study is to substantiate the implementation of a solar radiation utilization system that eliminates the use of water as a heat carrier, reduces the cost and dimensions of heat-utilizing elements, and at the same time maintains the simplicity and reliability of known systems.

Research results. Thermoelectric effects, due to their valuable properties, have found wide practical application in various areas of energy. Alternative energy devices based on the use of thermoelectric effects are characterized by long service life, relative simplicity of

design, reliability, silent operation and the absence of moving parts. They are also distinguished by their versatility in terms of supplying and removing thermal energy [2 - 6].

Therefore, it may be rational to use a low-potential heat utilization system based on Peltier elements.

Thermoelectric modules operating on the basis of the Peltier effect are designed to transfer thermal energy between two surfaces. They consist of semiconductor elements with P and N type conductivity, which are located between two insulating substrates. On the surface of these substrates there are contact pads through which the semiconductor elements are switched into a single electrical circuit. When current is passed through this electrical circuit, thermal energy is transferred from one substrate to another: one surface is cooled due to a drop in temperature, and on the other, on the contrary, the temperature increases. The principle of operation of Peltier elements is based on the contact of two conductive materials that have different electron energy levels in the conduction band. A feature of this system is that the semiconductor elements are located on both sides of the noise protection screen [6 – 9].

In [9] the process of energy conversion in thermoelectric modules (TEM) was studied in detail and the corresponding dependencies were obtained (Fig. 3).

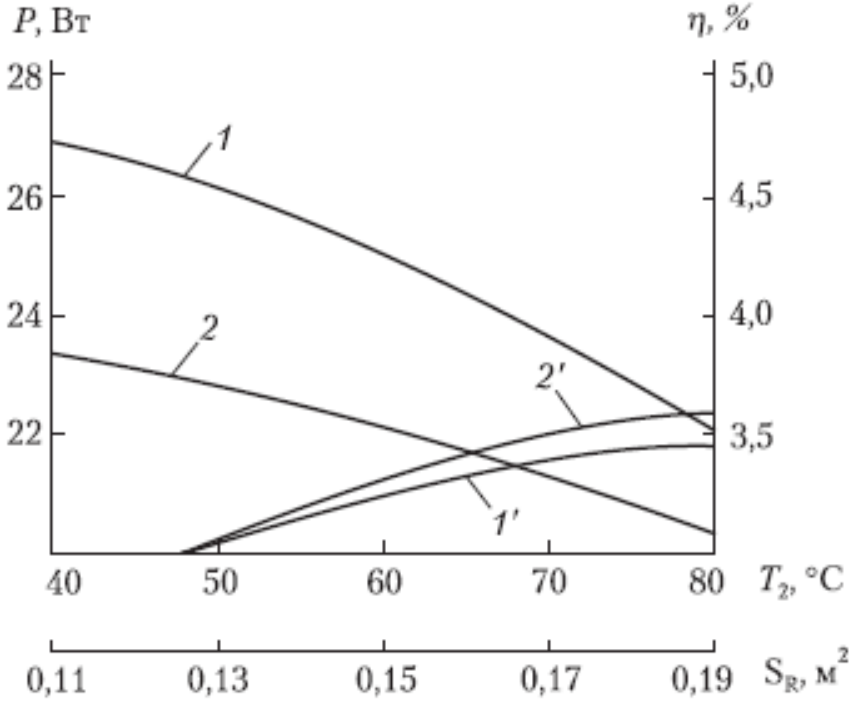

Fig. 3. Dependence of electric power P (1, 1`) and efficiency η (2, 2`) of thermoelectric module on temperature T_2 of cold side (1, 2) and area of heat-receiving surface of hot surface (1`, 2`);
$T_2 = 60°C$, $T_1 = 20°C$

For technical implementation of the specified task, the most promising are lead telluride (PbTe) with ZT 1,5-1,8 at 400…500 °C and magnesium silicide (Mg_2Si) with quality parameter ZT 1,0-1,3, which has lower cost and better environmental friendliness. For low-temperature heat, bismuth telluride (Bi_2Te_3) with ZT 1,0 … 1,2, is used, which provides efficiency of 6 … 8 %. New semi-Heusler alloys and skutterudites demonstrate ZT up to 1,7 with high mechanical stability.

TEM integration is accompanied by a number of significant challenges. Temperature fluctuations provoke thermal stresses, which can negatively affect the operation of the system. Corrosion caused by sulfur compounds deteriorates the efficiency of heat transfer. Vibrations, in turn, can cause damage to the fragile semiconductors used in the TEM design [10].

In [11], based on the numerical calculation method, the operating characteristics of thermoelectric modules were determined by such parameters as current density (j), voltage (U), electric field strength (E), temperature difference (Δt) between hot and cold contact plates, heat flux density (q), resistive heating (J), equivalent stress (σ) and deformations (ε) when the operating current changes in the range from 0 to 5 A.

It is proven that the use of compensators in the form of plate-springs on the hot side of thermoelectric module structures significantly affects thermal stresses depending on the change in their thickness. At the same time, the analysis of the equivalent stress (σ) functions when varying the current strength in the range of 0 ... 5 A revealed the presence of an extreme point near the current strength value of 4.1 A. After this point, the nature of the dependence changes, and the values of the equivalent stress (σ) increase rapidly. At the same time, it is noted that the use of compensated switching plates on the hot side of the modules did not lead to a decrease in the efficiency of the thermoelectric Peltier effect.

Simultaneously with the implementation of TEM, it is necessary to provide for the use of an appropriate information measuring system of the heat utilization complex. The modern concept of equipment operation until reaching a pre-failure state is based on various monitoring methods. These methods include the early detection of defects and damage. For the practical application of this concept, it is necessary to introduce advanced, convenient, automated means of monitoring TEM. However, this significantly complicates the control and management processes. Current directions in the development of modern operating methods indicate that the integration of reliable, verified, resistant to destabilizing factors measuring devices into microprocessor measuring systems contributes to increasing the efficiency and reliability of the functioning of any heat utilization complex. Currently, existing means of monitoring the technical condition operate under conditions of numerous destabilizing factors, in particular strong electromagnetic and thermal fields, vibrations and the influence of high-power electrical equipment. These factors limit the possibilities of providing control and management. Analysis of existing technical solutions shows that new means of technical control are necessary to ensure effective operation and repair of TEM. Particular attention should be paid to the development of devices based on fiber optics, which will be less sensitive to the influence of most operational destabilizing factors [12 - 14].

Conclusions. The integration of TEM into the energy systems of transport highways opens up new opportunities for increasing their energy efficiency. Continuous advances in the development of thermoelectric materials, reduction in production costs, as well as increasing environmental requirements are creating favorable conditions for the implementation of this technology in the next ten years. The successful application of TEM makes it possible to generate up to 6% of the required electricity. It also reduces fuel consumption by 2.3% for the technological needs of highways. In addition, it

contributes to the reduction of greenhouse gas emissions. This supports the achievement of the decarbonization goals of the maritime sector.

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СИСТЕМИ УТИЛІЗАЦІЇ ТЕПЛА СОНЯЧНОГО ВИПРОМІНЮВАННЯ НА ОБ`ЄКТАХ МОРЕГОСПОДАРЧОГО КОМПЛЕКСУ

[1]Сандлер Альберт Кирилович
кандидат технічних наук, доцент
ORCID: https://orcid.org/0000-0002-0709-0542
[2]Романовська Ольга Романівна
старший викладач
ORCID: https://orcid.org/0000-0003-3386-836X
[3]Палагін Олександр Миколайович
кандидат технічних наук, доцент
ORCID: https://orcid.org/0000-0002-6533-5894
[1]Національний університет "Одеська морська академія"
[2,3]Дунайський інститут Національного університета
"Одеська морська академія", Україна

Анотація. Одним зі шляхів вирішення проблеми енергозбереження є розробка технологій глибокої утилізації теплоти вторинних об'єктів морегосподарчого комплекса. Впровадження таких технологій дозволяє суттєво підвищити ефективність використання теплового потенціалу палива й забезпечити його економію, а також поліпшити екологічну обстановку за рахунок зниження викидів у навколишнє середовище шкідливих речовин. Розробка й впровадження теплоутилізаційних технологій сполучені з необхідністю рішення низки досить складних науково-технічних завдань.

Утилізаційні технології, як правило, впроваджуються в процесі модернізації або реконструкції існуючих об`єктів. Поставлена задача вирішується тим, що система утилізації низькопотенційного тепла, яка складається з елементів Пельтьє з телуріду вісмуту та германіду кремнію, які сполучені з первинними частинами металевими стрижнями та комутаційними пристроями для зв`язку з електромережою. Особливість застосування полягає у використанні площі звукозахисних екранів, які огороджують автошляхі морегосподарчої інфраструктури.

Ключові слова: утилізація, елементи Пельтьє, звукозахисний екран.

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